JOINT INSTITUTE FOR NUCLEAR RESEARCH

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Laboratory of Theoretical Physics

V.S. Barashenkov
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" MULTIPLE PRODUCTION OF NONSTABLE PARTICLES IN PION NUCLEON COLLISION "

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Abstract:

The statistical theory of multiple production of pions, nucleons, nonstable particles and antiparticles in (π N) - collisions is considered using the method described in [1], [2]. The deductions of the theory may be put into agreement with the experimental data if assume that "strange" and "usual" particles are produced in different space volumes.

Introduction

In papers [1], [2] it was shown that in case of (NN)-collisions the relative multiplicity which is predicted by the statistical theory of multiple production and the charge distribution of secondary particles agree well enough with experiment when we are concerned with pions and nucleons. But it is in sharp conflict with experiment for strange particles. In order to bring the aforementioned into agreement with experiment it was suggested to introduce one more parameter-radius of the space-region where the "strange" particles are "crystallized". It should be noted that the considered model is essentially different from that of Lepore and Neumann [3] where the diffusion of the boundary of the space region is assumed, however, to be identiacal for different kinds of particles.

In this paper the model [1], [2] is applied for the consideration of the multiple production of particles in (π N) - collisions.

2. Results of Fermi-Belenky Model

In Table 1 the theoretical and experimental values of the ratio $\frac{\sigma_{st}}{\sigma_o}$ of the probability of strange particle production to the probability of inelastic pion and nucleon production under the assumption that both strange ($S \neq 0$) and usual ($S = 0$) particles are produced in the same space volume with the radius equal to the Compton pion wave length*. As well as in case of (NN) - collisions the theoretical value of this ratio exceeds many times its experimental value. An analogous result may be obtained also in the case if we assume that all these particles are produced in the volume with the radius of the order of K-meson Compton wave length. Let us consider the mechanism of the multiple production of strange particles more in detail.

3. The Results of "Compound Particle" Model

Because of strong interaction in pion-nucleon collision a "compound particle" is originally produced. The fact that the nucleon "crystallization" starts simultaneuosly with pions from the volume the radius of which being $\sim(\hbar/m_{\pi}c)$ is also accounted for this strong interaction. Therefore only one parameter - the volume of "crystallization" region** is included into Fermi statistical theory. Quite another situation is for strange particles. We must consider that pion interaction with K-mesons is considerably less than with the nucleons (otherwise σ_{st}/σ_0 is much more than the experimental value as was shown above). Due to this the

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* In the cross-section of elastic production σ_0 the cases of "elastic production" of only one pair (π N) are not taken into account:

$$(N\pi):\ \sigma_0 = \sum_{n=2} \sigma(N\cdot n\pi) + \sum_{n=0} \sigma(\bar{N}\cdot 2N\cdot n\pi)$$

** This fact is also reflected in the anomalous core diffusion in the nucleon.

"flying away" of free K-mesons will start from smaller region with the radius of the order of K-meson Compton wave length. Then in the formula of the statistical weight the Fermi space factor V_1 is changed for V_2 or V_3*.

The first case corresponds to Schvinger and Gell-Mann hypothesis on the global pion interaction with baryons|7|, the second case will take place if pion interaction with Λ-; Σ-; Ξ -particles is considerably less than with the nucleons. As can be seen from Table 2 the calculation with the weight factor V_2 (π-p) collisions is found to be more close to experiment |10|**. Since most of strange particles are produced near the threshold one would not expect good agreement with the experiment from the statistical theory. However, the minimum of the ratio σ_{st}/σ_0 in the region ~ 1BeV which is often of the statistical character is confirmed by the experiment|10|.

In Table 3 the results are given of the calculation of the relative probability of possible reactions in (π^--p) and (π^+-p)-collisions with the energy E = 5 BeV for the case weght factor V_2 and V_3 (respectively W_2% and W_3%). In Table 4 the corresponding results are given for (π^+ p) and (π^--p) - collisions with the energy E = 7 BeV. In both Tables the probabilities W_i are expressed in percents. The calculations are made under the same assumptions and using the same method as in|2|.

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* We use the notation as in |1|,|2|.

** An anologous calculation for (p-p) collisions at 3 BeV gives 16% for V_1; 5,7% for V_2, 0,27% for V_3. The second event is also found to be the closest to the experiment ~ 3%.

In Conclusion we wish to thank Professor D.I. Blokhintsev for discussions. We are also grateful to Duan-I-Shi, V.L. Evteev and G.N. Tentyukova for assistance in numerical calculations.

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Table 1

E BeV	Theory	Experiments
0,95	24%	~ 4%
I,3	I9%	
5,0	I34%	
7,0	20I%	

Table 2

E BeV	σ_{st}/σ_0	
	V_2	V_3
0,95	I3%	0,6%
I,3	9%	0,4%

Table 3*

REACTION		(π^+p)		(π^-p)	
	n	W_2%	W_3%	W_2%	W_3%
$N\cdot n\cdot\pi$	I	0,6I4	0,68I	0,722	0,8I8
	2	8,68	9,67	I0,2	II,6
	3	32,0	35,7	30,7	34,7
	4	3I,7	35,3	30,0	34,0
	5	II,I	I2,4	I0,0	II,3
	6	I,42	I,58	I,26	I,42
$\Lambda K n\pi$	0	0	0	0,246	0,0I27
	I	I,64	0,0820	I,94	0,0984
	2	I,4I	0,0696	I,66	0,0835
	3	0,53I	0,0260	0,536	0,0267
$\Sigma K\,\boxed{n\pi}$	0	0,284	0,0I43	0,335	0,0I72
	I	2,88	0,I44	3,40	0,I73
	2	2,8I	0,I39	2,84	0,I43
	3	I,02	0,0499	0,987	0,0490
$NK\bar{K}\cdot n\pi$	0	0,0753	0,0839	0,I53	0,I74
	I	0,4I5	0,463	0,4I8	0,473
	2	0,253	0,282	0,252	0,286
	3	0,0223	0,0249	0,0209	0,0237

Continuation of Table 3

REACTION	n	$(\pi^{+}p)$ W_2%	$(\pi^{+}p)$ W_3%	$(\pi^{-}p)$ W_2%	$(\pi^{-}p)$ W_3%
$2N\bar{N}\cdot n\pi$	0	I,37	I,52	2,77	3,I5
	I	I,5I	I,68	I,44	I,29
$\Xi\, 2k\, n\pi$	0	0,0I76	0,0^{3}670	0,0357	0,0^{2}I39
	I	0,028I	0,0^{2}I07	0,0332	0,0^{2}I29
	2	0,0^{2}I75	0,0^{4}666	0,0^{2}I85	0,0^{4}7I6
$\Lambda\bar{\Lambda}N\, n\pi$	0	0	0	0,0706	0,0^{2}I26
$\Lambda\, 2k\bar{k}\, n\pi$	0	0,0^{3}I78	0,0^{5}6I0	0,0^{3}36I	0,0^{4}I26
$\Sigma\, 2k\bar{k}\, n\pi$	0	0,0^{3}360	0,0^{4}I23	0,0^{3}424	0,0^{4}I48

* The quantity in brackets signifies the~~n~~ number of nulls, for instance: $0{,}0^{3}3 = 0{,}003$

Table 4**

REACTION	n	(π^+p) $W_2\%$	(π^+p) $W_3\%$	(π^-p) $W_2\%$	(π^-p) $W_3\%$
$N\cdot n\pi$	I	0,I44	0,I72	0,I70	0,209
	2	3,06	3,64	3,62	4,43
	3	I6,2	I9,3	I5,7	I9,2
	4	24,8	29,4	23,5	28,7
	5	I3,8	I6,4	I2,5	I5,2
	6	3,07	3,65	2,72	3,32
	7	0,363	0,432	0,3I6	0,386
$\Lambda\cdot K\cdot n\pi$	0	0	0	0,0595	$0,0^{2}334$
	I	0,622	0,0332	0,734	0,0403
	2	I,49	0,0785	I,75	0,0954
	3	0,959	0,0506	0,980	0,0526
	4	0,253	0,0I3I	0,245	0,0I33
1) $\Sigma K\cdot n\pi$	0	0,069I	$0,0^{2}373$	0,08I5	$0,0^{2}453$
	I	I,2I	0,0648	I,43	0,0788
	2	3,25	0,I72	3,29	0,I78
	3	I,86	0,0972	I,80	0,0967
	4	0,253	0,0I3I	0,234	0,0I25

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$K\Sigma$

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REACTION		(π^+p)		(π^-p)		
	n	W_2 %	W_3 %	W_2 %	W_3 %	
2) $NK\bar{K}\cdot n\pi$	0	0	0	0,0276	0,0342	
	I	0,305	0,368	0,32I	0,393	
$K\bar{K}$	2	0,545	0,648	0,550	0,669	
	3	0,I95	0,232	0,I82	0,223	17
	4	0,0I0I	0,0I20	$0{,}0^2924$	0,0II3	13
$2N\bar{N}\cdot n\pi$	0	I,47	I,75	2,98 √	3,67	
	I	I0,3	I2,3	8,55 √	I0,4	
	2	8,8I	I0,5	9,9I √	I2,I	
	3	0,486	0,43I	0,204	0,249	
$\Xi 2K\cdot n\pi$	0	$0{,}0^2990$	$0{,}0^3405$	0,020I	$0{,}0^3850$	
	I	0,0495	$0{,}0^2202$	0,0584	$0{,}0^2245$	
$2K\Xi$	2	0,0239	$0{,}0^3969$	0,0253	$0{,}0^2I06$	
$\Lambda 2K\bar{K}\,n\pi$	0	$0{,}0^3239$	$0{,}0^5873$	$0{,}0^3485$	$0{,}0^4I83$	
	I	$0{,}0^3I04$	$0{,}0^5378$	$0{,}0^3I22$	$0{,}0^5459$	√
$\Sigma 2K\bar{K}\,n\pi$	0	$0{,}0^3377$	$0{,}0^4I37$	$0{,}0^3444$	$0{,}0^4I67$	
	I	$0{,}0^3I7I$	$0{,}0^5622$	$0{,}0^3I8I$	$0{,}0^5677$	√
$\Lambda\bar{\Lambda}N\cdot n\pi$	0	0	0	I,05 √	0,0204	
	I	0,844	0,0I49	0,433	$0{,}0^27I9$	

REACTION		(π^+p)		(π^-p)	
	n	W_2 %	W_3 %	W_2 %	W_3 %
$\Sigma\bar{\Sigma}N\,n\pi$	0	1,43	0,0267	1,69	0,0324
	1	0,690	$0{,}0^{2}251$	0,662	$0{,}0^{2}295$
$\Lambda\bar{\Sigma}N\,n\pi$	0	0,960	0,0179	1,13	0,0217
	1	0,572	$0{,}0^{2}974$	0,675	0,0118
$\bar{\Lambda}\Sigma N\,n\pi$	0	0,960	0,0179	1,13	0,0217
	1	0,572	$0{,}0^{2}974$	0,675	0,0118
$\bar{\Xi}\,2\Lambda$	0	0	0	0,0741	$0{,}0^{4}494$
$\bar{\Xi}\,2\Sigma$	0	0,0192	$0{,}0^{4}123$	0,0226	$0{,}0^{4}149$
$\bar{\Xi}\,\Lambda\,\Sigma$	0	0,0783	$0{,}0^{4}502$	0,0925	$0{,}0^{4}610$
2) $\Xi\bar{\Xi}N$	0,	0,130	$0{,}0^{2}241$	0,263	$0{,}0^{2}506$
$\Lambda N\bar{N}K$	0	0,0139	$0{,}0^{3}732$	0,0281	$0{,}0^{2}154$
$\bar{\Lambda}\,2NK\bar{}$	0	$0{,}0^{2}693$	$0{,}0^{3}366$	0,0141	$0{,}0^{3}768$
1) $\Sigma N\bar{N}K$	0	0,0157	$0{,}0^{3}828$	0,0185	$0{,}0^{2}101$
1) $\bar{\Sigma}\,2N\bar{K}$	0	$0{,}0^{2}784$	$0{,}0^{3}414$	$0{,}0^{2}926$	$0{,}0^{3}503$

$\Sigma\ \bar{\Sigma}$

Co şi la opoziţie
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**/ The quantity in brakets signifies the number of nulls.